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(54) Radio set with an antenna

(57) A radio set comprises an antenna (100) which is a λ/2 monopole antenna capacitively coupled to the radio circuit on a circuit substrate (200) by way of a capacitor (110) and powered by the circuit. A ground pattern (2011) is formed on the circuit substrate (201) in a region of about λ/2 at the side of the antenna (100) as viewed in the axial direction of the antenna (100) and another ground pattern (2012) is formed in the remaining region of about λ/2 and electrically connected to the ground pattern (2011) by way of an inductor (301). The inductance of the inductor (301) is so selected that the phase of the electric current flowing between the ground pattern (2011) and the ground pattern (2012) is advanced by 180° at the operating frequency of the wavelength λ.

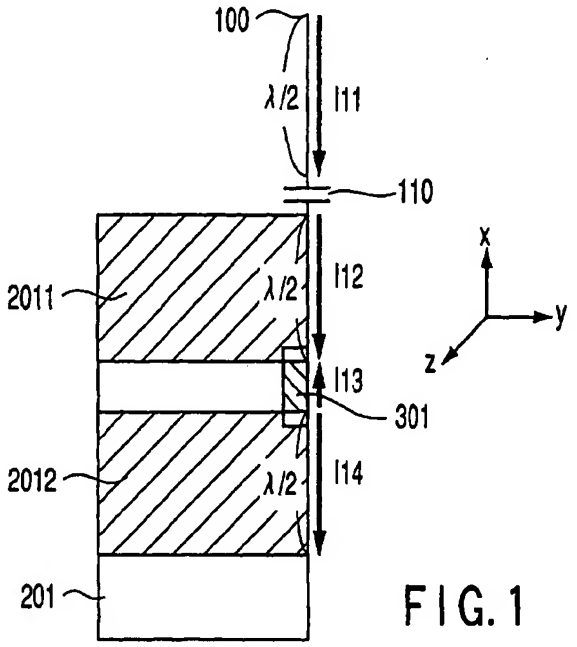

FIG. 1

EP 1 211 750 A2

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Description

[0001] This invention relates to a radio set that can be used for various mobile communication systems including mobile telephone systems.

[0002] FIG. 9 of the accompanying drawings schematically illustrates the positional relationship between the antenna 100 and the circuit substrate 200 of a typical known mobile phone set that can be used for various mobile communication systems including mobile telephone systems.

[0003] More specifically, FIG. 9 shows a radio set comprising an antenna 100 which is a λ/2 monopole antenna capacitively coupled to the radio circuit on the circuit substrate 200 by way of a capacitor 110 and powered by the circuit.

[0004] Such a radio set provides a radiation pattern shown in FIG. 10, as viewed in a direction perpendicular to the axis of the antenna 100, the front end of the antenna 100 being in the direction of 0°.

[0005] By comparing FIGS. 9 and 10, it will be appreciated that the axis running through 0° and ±180° and the one running through -90° and +90° in FIG. 10 respectively correspond to the x-axis and the y-axis in FIG. 10.

[0006] As seen from the radiation pattern, the radiation pattern of the known radio set involves null directions. In the case of FIG. 10, the directions of 120° and -120° are null directions.

[0007] The electric current I1 generated in the antenna 100 and the electric currents I2 and I3 generated in the circuit substrate 200 are responsible for the nulls. The arrows indicating the respective electric currents in FIG. 9 also show the phase relationships among the electric currents.

[0008] The phase of the electric current I1 generated in the antenna 100 and that of the electric current I3 generated in the circuit substrate 200 are inverted relative to each other so that the desired electric wave radiation by the electric current I1 and the electric wave radiation by the electric current I3 offset each other to produce the nulls.

[0009] Such nulls reduce both the signal reception level and the quality of the received signals to make it difficult to maintain the intended quality level for the received signals.

[0010] Most conventional radio sets generates a radiation pattern having nulls. Their reception levels fall, depending on the direction in which the target radio waves are coming. Due to the low reception levels, the conventional radio sets cannot have desired signal-receiving characteristics.

[0011] A radio set according to an aspect of the invention comprises:

an antenna for transmitting radio signals and receiving radio signals, a circuit substrate comprising a radio circuit for transmitting and receiving radio signals, and a plurality of ground patterns provided on said circuit substrate,

characterized in that said ground patterns are electrically connected by connection means, so as to generate electric currents which has the same phase as an electric current generated in said antenna, and said connection means is arranged to cause an electric current to flow, which has a phase opposite to the phase of the electric current generated in said antenna.

[0012] With a radio set according to the invention and having the above described configuration, as pointed out above, a plurality of ground patterns are arranged on the circuit substrate and connected to one another by connection means so as to generate an electric current with a phase the same as that of the electric current generated in the antenna, and the connection means are arranged so as to cause an electric current to flow with a phase inverted relative to that of the electric current generated in the antenna.

[0013] A radio set according to an aspect of the invention comprises:

an antenna for transmitting radio signals and receiving radio signals; and a circuit substrate comprising a ground pattern and a radio circuit for transmitting and receiving radio signals,

characterized in that said ground pattern has a notch at a position where an electric current having a phase opposite to the phase of an electric current generated in said antenna is likely to be generated, and said notch extends perpendicularly to the direction in which the electric current generated in said antenna flows, so as not to generate an electric current having a phase opposite to the phase of the electric current generated in said antenna.

[0014] As pointed out above, with a radio set according to the invention and having the above described configuration, the ground pattern of the circuit substrate is provided at a position apt to generate an electric current with a phase inverted relative to that of the electric current generated in the antenna with a notch directed perpendicularly relative to the direction of the flow of the electric current generated in the antenna so as not to generate an electric current with a phase inverted relative to that of the electric current generated in the antenna.

[0015] A radio set according to an aspect of the invention comprises:

an antenna for transmitting radio signals and receiving radio signals; and a circuit substrate comprising a ground pattern and a radio circuit for transmitting and receiving radio signals,

characterized in that said ground pattern has a projection at a position where an electric current having

a phase opposite to the phase of the electric current generated in said antenna is likely to be generated, and said projection extends perpendicularly to the direction in which the electric current generated in said antenna flows, so as not to generate an electric current having a phase opposite to the phase of the electric current generated in said antenna.

[0016] As pointed out above, with a radio set according to the invention and having the above described configuration, the ground pattern of the circuit substrate is provided at a position apt to generate an electric current with a phase inverted relative to that of the electric current generated in the antenna with a projection directed perpendicularly relative to the direction of the flow of the electric current generated in the antenna so as not to generate an electric current with a phase inverted relative to that of the electric current generated in the antenna.

[0017] A radio set according to an aspect of the invention comprises:

an antenna for transmitting radio signals and receiving radio signals and a circuit substrate comprising a radio circuit for transmitting and receiving radio signals,

characterized by further comprising:

a first ground pattern provided on said circuit substrate;
a second ground pattern provided on said circuit substrate; and
connection means for electrically connecting the first and second ground patterns, so as to make that electric currents flowing through said first and second ground patterns have the same phase as the electric current generated in said antenna.

[0018] With a radio set according to the invention and having the above described configuration, the first ground pattern and the second ground pattern are electrically connected to each other by connection means so as to make both the phase of the electric current flowing through the first ground pattern and that of the electric current flowing through the second ground pattern the same as that of the phase of the electric current generated in the antenna.

[0019] This summary of the invention does not necessarily describe all necessary features so that the invention may also be a sub-combination of these described features.

[0020] The invention can be more fully under stood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic circuit block diagram of the first embodiment of a radio set according to the invention;
FIG. 2 is a schematic illustration of the radiation pattern of the antenna of the radio set of FIG. 1;
FIG. 3 is a schematic circuit block diagram of the second embodiment of a radio set according to the invention;
FIG. 4 is a schematic circuit block diagram of an embodiment of a radio set according to the invention obtained by modifying the embodiment of FIG. 3 and substantially as effective as the embodiment of FIG. 3;
FIG. 5 is a schematic circuit block diagram of another embodiment of a radio set according to the invention also obtained by modifying the embodiment of FIG. 3 and substantially as effective as the embodiment of FIG. 3;
FIG. 6 is a schematic circuit block diagram of the third embodiment of radio set according to the invention;
FIG. 7 is a schematic circuit block diagram of an embodiment of a radio set according to the invention obtained by modifying the embodiment of FIG. 6 and substantially as effective as the embodiment of FIG. 6;
FIG. 8 is a schematic circuit block diagram of another embodiment of a radio set according to the invention also obtained by modifying the embodiment of FIG. 6 and substantially as effective as the embodiment of FIG. 6;
FIG. 9 is a schematic circuit block diagram of a known radio set; and
FIG. 10 is a schematic illustration of the radiation pattern of the antenna of the radio set of FIG. 9.

[0021] Now, the present invention will be described in greater detail by referring to the accompanying drawings that illustrate preferred embodiments of the invention.

[0022] FIG. 1 is a schematic circuit block diagram of the first embodiment of the radio set according to the invention. In FIG. 1, the components the same as those of the known radio set of FIG. 9 are denoted respectively by the same reference symbols. The embodiment will be described in terms of the configuration that affects the radio wave radiation pattern.

[0023] The radio set of FIG. 1 comprises an antenna 100 which is a $\lambda/2$ monopole antenna capacitively coupled to the radio circuit on a circuit substrate 201 by way of a capacitor 110 and powered by the circuit.

[0024] A ground pattern 2011 is formed on the circuit substrate 201 in a region of about $\lambda/2$ at the side of the antenna 100 as viewed in the axial direction of the antenna 100, and another ground pattern 2012 is formed in the remaining region of about $\lambda/2$ and electrically connected to the ground pattern 2011 by way of an inductor 301.

[0025] Note that λ denotes the wavelength at the operating frequency of the circuit substrate 201. The inductance of the inductor 301 is so selected that the

phase of the electric current flowing between the ground pattern 2011 and the ground pattern 2012 is advanced by 180° at the operating frequency.

[0026] With the above described arrangement, both the phase of the electric current I12 generated in the ground pattern 2011 and that of the electric current I14 generated in the ground pattern 2012 are the same as that of the electric current 111 generated in the antenna 100 and hence only the electric current I13 flowing through the inductor 301 shows a phase inverted relative to that of the electric current I11.

[0027] Thus, in the radio set having the above described configuration, an inductor 301 is arranged between the two ground patterns 2011, 2012 on the circuit substrate 201 in such a way that the phase of the electric current flowing between the ground patterns 2011, 2012 is inverted, or advanced by 180°, and the length of the route through which the electric current I13 whose phase is inverted relative to that of the electric current I11 flows is minimized.

[0028] Therefore, the route in which the current I13 opposite in phase to the current I11 flows is short in the radio set described above. The component of the current I11, which offsets the radio-wave radiation, decreases, reducing the nulls in the radiation pattern as shown in FIG. 2. Thanks to the reduction of nulls, the radio set can exhibit good signal-receiving characteristics.

[0029] The present invention is by no means limited to the above described embodiment. For example, while an inductor 301 is arranged in the above embodiment for the purpose of phase inversion, the inductor 301 may be replaced by a capacitor for phase inversion.

[0030] Now, the second embodiment of radio set according to the invention will be described. FIG. 3 is a schematic circuit block diagram of the second embodiment.

[0031] In FIG. 3, the components the same as those of the known radio set of FIG. 9 are denoted respectively by the same reference symbols. The embodiment will be described in terms of the configuration that affects the radio wave radiation pattern.

[0032] The radio set of FIG. 3 comprises an antenna 100 which is a λ/2 monopole antenna capacitively coupled to the radio circuit on a circuit substrate 202 by way of a capacitor 110 and powered by the circuit.

[0033] A ground pattern 2021 having a notch 2022 directed perpendicularly relative to the axial direction of the antenna 100 is formed on the circuit substrate 202.

[0034] Note that the notch 2022 is formed at the position 302 separated by a distance of λ/2 from both of the opposite ends of the ground pattern 2021 as viewed in the axial direction of the antenna 100.

[0035] Also note that λ denotes the wavelength at the operating frequency of the circuit substrate 202.

[0036] With the above described arrangement, both the phase of the electric current I22 generated in a region of the ground pattern located close to the antenna 100 relative to the notch 2022 and that of the electric current I25 generated in a region of the ground pattern remote from the antenna 100 relative to the notch 2022 are the same as that of the electric current I21 generated in the antenna 100 and the electric currents I23, I24 that flow along the notch 2022 are directed perpendicularly relative to the axis of the antenna 100.

[0037] Thus, in the radio set having the above described configuration, the circuit substrate 202 is provided with a notch 2022 at the position 302 equally dividing the circuit substrate 202 into two parts showing a length of λ/2 in order to prevent any electric current showing a phase inverted relative to that of the electric current I1 from being generated.

[0038] No current that is opposite in phase to the current I1 is generated in the radio set so constructed as described above. This reduces the number of nulls in the radiation pattern. As a result, the radio set has desirable signal-receiving characteristics.

[0039] The present invention is by no means limited to the above described embodiment. For example, while the notch formed in the circuit substrate 202 may be replaced by a pair of notches as shown in FIG. 4, or a notch as shown in FIG. 5, to provide a similar effect of preventing any electric current showing a phase inverted relative to that of the electric current I1 from being generated.

[0040] Now, the third embodiment of a radio set according to the invention will be described. FIG. 6 is a schematic circuit block diagram of the second embodiment.

[0041] In FIG. 6, the components the same as those of the known radio set of FIG. 9 are denoted respectively by the same reference symbols. The embodiment will be described in terms of the configuration that affects the radio wave radiation pattern.

[0042] The radio set of FIG. 6 comprises an antenna 100 which is a λ/2 monopole antenna capacitively coupled to the radio circuit on a circuit substrate 203 by way of a capacitor 110 and powered by the circuit.

[0043] A ground pattern 2031 having a projection 2032 directed perpendicularly relative to the axial direction of the antenna 100 is formed on the circuit substrate 203.

[0044] Note that the projection 2032 is formed at the position 303 separated by a distance of λ/2 from both of the opposite ends of the ground pattern 2031 as viewed in the axial direction of the antenna 100.

[0045] Also note that λ denotes the wavelength at the operating frequency of the circuit substrate 203.

[0046] With the above described arrangement, both the phase of the electric current I23 generated in a region of the ground pattern located close to the antenna 100 relative to the projection 2032 and that of the electric current I35 generated in a region of the ground pattern remote from the antenna 100 relative to the projection 2032 are the same as that of the electric current I31 generated in the antenna 100 and the electric currents I33,

I34 that flow along the projection 2032 are directed perpendicularly relative to the axis of the antenna 100.

[0047] Thus, in the radio set having the above described configuration, the circuit substrate 202 is provided with a projection 2032 at the position 303 equally dividing the circuit substrate 202 into two parts showing a length of $\lambda/2$ in order to prevent any electric current showing a phase inverted relative to that of the electric current I1 from being generated.

[0048] No current that is opposite in phase to the current I1 is generated in the radio set so constructed as described above. This reduces the number of nulls in the radiation pattern. As a result, the radio set acquires good signal-receiving characteristics.

[0049] The present invention is by no means limited to the above described embodiment. For example, while the projection formed in the circuit substrate 203 may be folded onto the circuit substrate 203 as shown in FIG. 7 or replaced by a pair of projections as shown in FIG. 8 that may or may not be folded onto the circuit substrate 203, so long as such a projection or projections can provide a similar effect of preventing any electric current showing a phase inverted relative to that of the electric current I1 from being generated.

[0050] The present invention is not limited to the above described embodiments.

[0051] For example, while the notch 2022 and the projection 2032 of the above described embodiments are made to extend in a direction perpendicular to the axis of the antenna 100, they may not be arranged strictly in a perpendicular direction to the axis of the antenna 100 so long as they provide a similar effect.

[0052] Furthermore, the above described embodiments may be modified and/or altered appropriately without departing from the scope of the present invention.

Claims

1. A radio set comprising an antenna (100) for transmitting radio signals and receiving radio signals, a circuit substrate (201) comprising a radio circuit for transmitting and receiving radio signals, and a plurality of ground patterns (2011, 2012) provided on said circuit substrate (201),

   characterized in that said ground patterns (2011, 2012) are electrically connected by connection means (301), so as to generate electric currents (I12, I14) which has the same phase as an electric current (I11) generated in said antenna (100), and said connection means (301) is arranged to cause an electric current (I13) to flow, which has a phase opposite to the phase of the electric current (I11) generated in said antenna (100).

2. The radio set according to claim 1, **characterized in that** said connection means (301) is an inductor.

3. The radio set according to claim 1, **characterized in that** said connection means (301) is a capacitor.

4. A radio set comprising an antenna (100) for transmitting radio signals and receiving radio signals; and a circuit substrate (202) comprising a ground pattern (2021) and a radio circuit for transmitting and receiving radio signals,

   characterized in that said ground pattern (2021) has a notch (2022) at a position (302) where an electric current having a phase opposite to the phase of an electric current (I21) generated in said antenna (100) is likely to be generated, and said notch (2022) extends perpendicularly to the direction in which the electric current (I21) generated in said antenna (100) flows, so as not to generate an electric current having a phase opposite to the phase of the electric current (I21) generated in said antenna (100).

5. A radio set comprising an antenna (100) for transmitting radio signals and receiving radio signals; and a circuit substrate (203) comprising a ground pattern (2031) and a radio circuit for transmitting and receiving radio signals,

   characterized in that said ground pattern (2031) has a projection (2032) at a position (303) where an electric current having a phase opposite to the phase of the electric current (I31) generated in said antenna (100) is likely to be generated, and said projection (2032) extends perpendicularly to the direction in which the electric current (I31) generated in said antenna (100) flows, so as not to generate an electric current having a phase opposite to the phase of the electric current (I31) generated in said antenna (100).

6. A radio set comprising an antenna (100) for transmitting radio signals and receiving radio signals and a circuit substrate (201) comprising a radio circuit for transmitting and receiving radio signals,

   characterized by further comprising:

   a first ground pattern (2011) provided on said circuit substrate (201);
   a second ground pattern (2012) provided on said circuit substrate (201); and
   connection means (301) for electrically connecting the first and second ground patterns (2011, 2012), so as to make that electric currents (I12, I14) flowing through said first and second ground patterns (2011, 2012) have the same phase as the electric current (I11) generated in said antenna (100).

7. The radio set according to claim 6, **characterized in that** said connection means (301) is an inductor.

8. The radio set according to claim 6, **characterized in that** said connection means (301) is a capacitor.

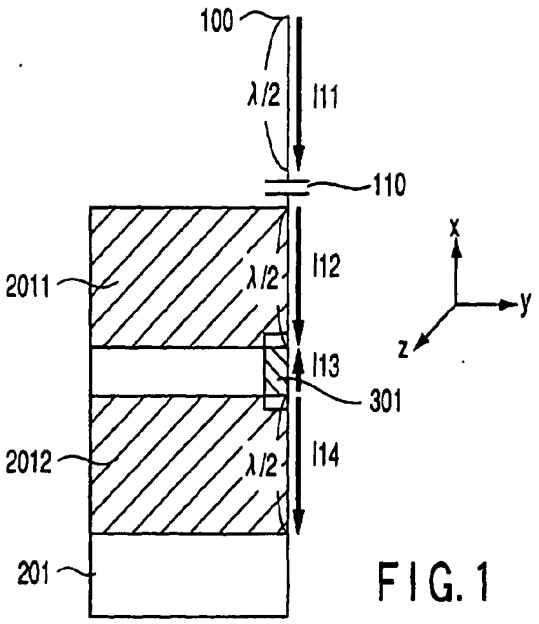
100
λ/2
I11
110
2011
λ/2
I12
I13
301
2012
λ/2
I14
201
x
y
z

FIG. 1

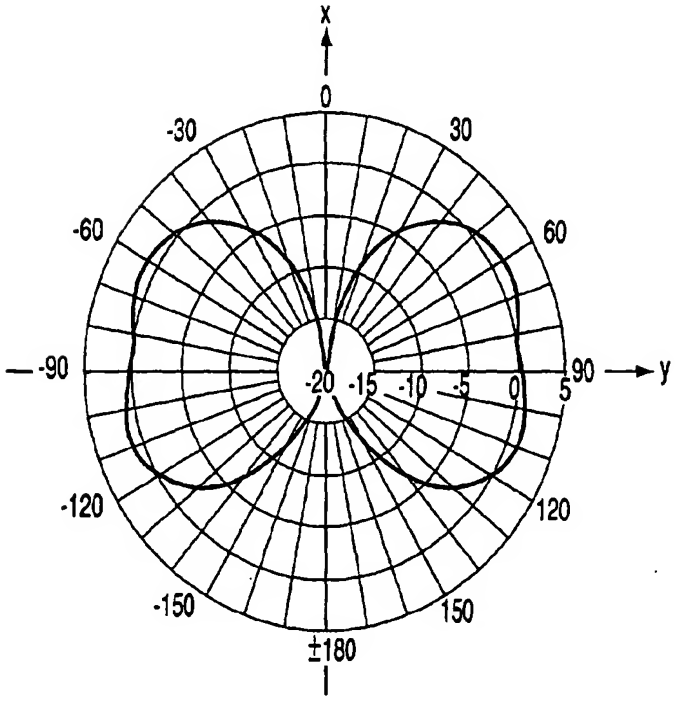
x
0
-30
30
-60
60
-90
90
y
-20
-15
-10
-5
0
5
-120
120
-150
150
±180

FIG. 2

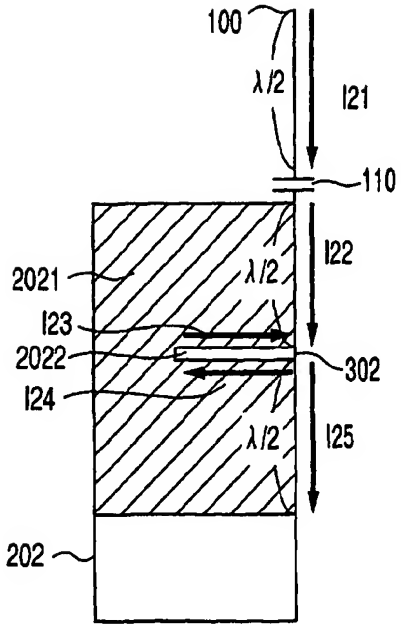

FIG. 3

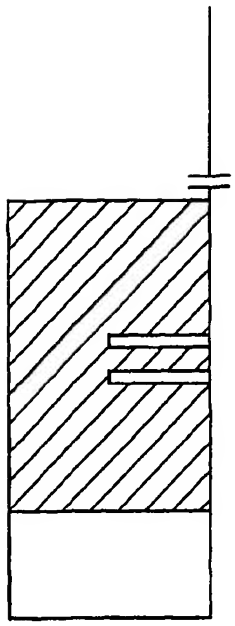

FIG. 4

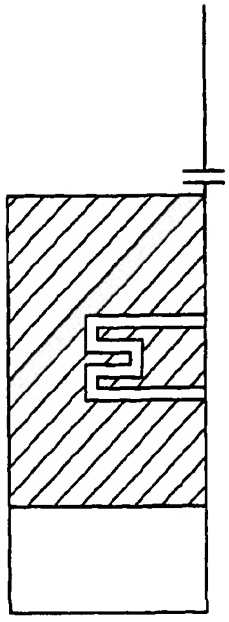

FIG. 5

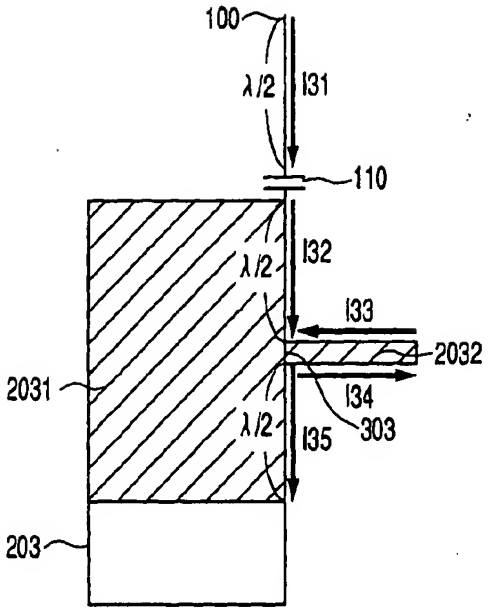

FIG. 6

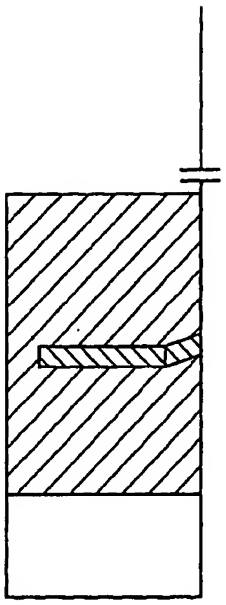

FIG. 7

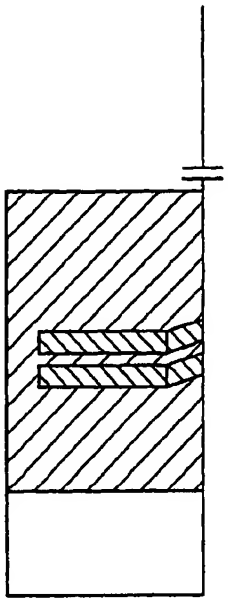

FIG. 8

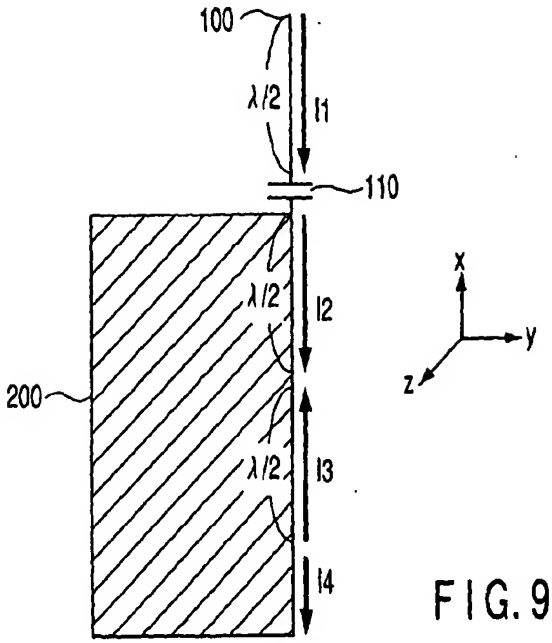
100
λ/2
I1
110
λ/2
I2
200
λ/2
I3
I4
x
y
z

FIG. 9

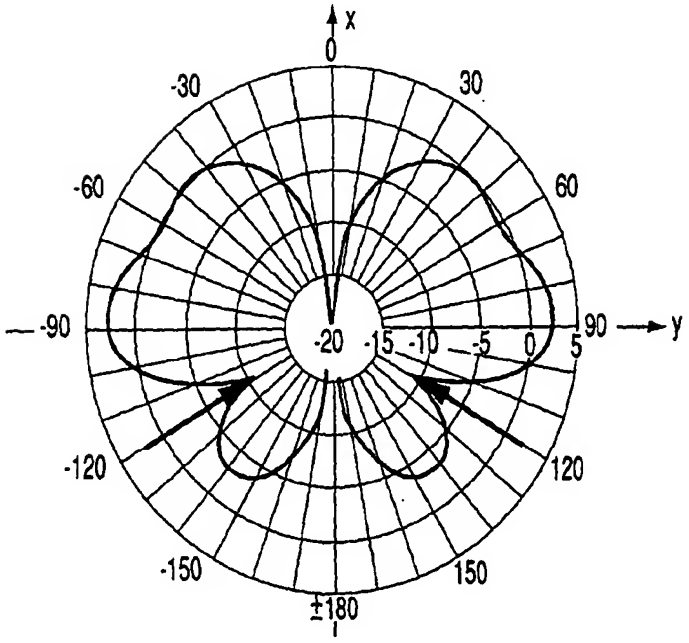
x
0
-30
30
-60
60
-90
90
y
-20
-15
-10
-5
0
5
-120
120
-150
150
±180

FIG. 10